PROJECT TITLE: Circulation in the Vicinity of Descending Overflows

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LONG TERM GOALS

The long-term goal of this project is to contribute to our understanding of the circulation, exchange, and environment between marginal seas and the open ocean.

OBJECTIVE

To better understand the mean and time-dependent circulations induced in the upper ocean by turbulent entrainment in the vicinity of steep bottom topography.

APPROACH

Idealized numerical modelling studies are used in conjunction with theory to understand the large scale circulations that are forced by entrainment into spatially variable mixing regions. The results are interpreted and understood by making use of potential vorticity budgets, integral constraints, and thermodynamic balances. Geometries under study include: entrainment in the open ocean, entrainment near steep topography, and entrainment near ridges and seamounts.

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WORK COMPLETED

An isopycnal model has been applied to the study of the large scale circulation induced by localized diapycnal mixing in simply and multiply connected domains. Analytic boundary layer solutions have been developed to quantify the dissipation resulting from mixing near boundaries. Fundamental integral constraints have been developed to interpret the resulting circulation patterns and transports as a function of the mixing and topographic parameters.

A nonlinear analytic two-layer model has been developed to study the circulation forced by spatially variable diapycnal mixing over a sloping bottom. Two non-dimensional numbers control the strength of the horizontal circulation and the importance of the nonlinear terms. A series of idealized calculations and an application to the circulation in the deep Brazil Basin have been completed.

Analytic models of the wind- and buoyancy-forced circulation in

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marginal seas have also been developed and applied to the
circulation around Australia and the circulation in the Sea of
Japan.

RESULTS

The strong, large-scale horizontal recirculation that is forced by
open ocean diapycnal mixing is gradually replaced by a weak,
unidirectional flow into or out of the mixing region as the
mixing is confined near a horizontal boundary. The viscous
potential vorticity flux into the boundary replaces the strong
horizontal recirculation gyre in the potential vorticity budget.
However, if this mixing is along the western side of an island or
mid-ocean ridge, the dissipation within the mixing region requires that
a strong, large-scale horizontal circulation flow around the topography,
connecting the adjacent basins and sometimes extending far from the
region of mixing. Diapycnal mixing in the open ocean
to the east of an island or ridge also requires a horizontal circulation
around the topography to the west.

A meridional gradient in sea surface temperature forces an
eastward geostrophic flow in the upper ocean. A buoyancy-forced
boundary current is formed as this flow impinges on an
eastern boundary. If the boundary is an island, then
constraints imposed by a circulation integral around the island
require that a large-scale circulation develop that connects the
two basins separated by the island. Application of this
model to the circulation around Australia indicates that
the transport from the Pacific to Indian Ocean is reduced
in the upper 200 m and enhanced at mid-depths compared to that
expected from wind-driven theory. The theory compares well with
results from an idealized primitive equation numerical model.

Diapycnal mixing over a sloping bottom results in a weak,
unidirectional flow into or out of the mixing region in the
deep ocean, and a strong horizontal recirculation in the upper
ocean. In this inviscid case, the deep recirculation is exactly
eliminated by the interaction of the deep flow with the bottom topography,
even when the flow is nonlinear. Application of this analytic
model to the deep Brazil Basin produces horizontal and vertical
circulations that are in good agreement with recent observations.

IMPACTS/APPLICATION

These results indicate that mixing near topography can force
strong circulations far from the region of mixing. The
exchange between marginal seas and the open ocean will be strongly
·dependent on whether the marginal sea is connected to the open
ocean by one strait (e.g. the Mediterranean Sea) or by two or more
straits (e.g. the Sea of Japan). Spatially variable mixing over
even a very weakly sloping bottom results in a fundamentally different
horizontal circulation than does mixing over a flat bottom.

PUBLICATIONS

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14. ABSTRACT

Analytic and numerical models have been used to study the large-scale circulation and exchange between marginal seas and the open ocean resulting from diapycnal mixing near lateral boundaries. The results indicate that mixing near topography can force strong circulations far from the region of mixing, sometimes extending into an adjacent ocean basin. The exchange between marginal seas and the open ocean will be strongly dependent on whether the marginal sea is connected to the open ocean by one strait (e.g., the Mediterranean Sea) or by two or more straits (e.g., the Sea of Japan). Islands and ridges generally provide a very effective means for communication and exchange between adjacent ocean basins. Spatially variable mixing over even a very weakly sloping bottom results in a fundamentally different horizontal circulation than does mixing over a flat bottom.

15. SUBJECT TERMS

Turbulent mixing, marginal seas, bottom topography

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